v1: 14 March 2024

Research Article

Enhancing Supply Chain Management Risk Mitigation: A House of Risk Methodology Applied to Brick Manufacturing in Aceh Besar Regency

Peer-approved: 14 March 2024

Qeios, Vol. 6 (2024)
ISSN: 2632-3834

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Effective supply chain management is imperative for the seamless operation of manufacturing facilities, ensuring the timely delivery of goods and services to customers. However, the inherent complexity of supply chain systems introduces various risks and uncertainties that can significantly impact factory performance and the broader business sector. This research addresses the challenges faced by a brick manufacturing factory in Aceh Besar Regency, highlighting the absence of a well-structured risk management framework, inadequate mitigation planning, and suboptimal risk identification methods within the supply chain. To address these shortcomings, this study employs the House of Risk (HoR) methodology, utilizing it to identify risk events and agents within the supply chain. Mitigation strategies are designed based on the Aggregate Risk Potential (ARP). Data for the study were gathered through interviews and questionnaires completed by 12 respondents from three brick manufacturing factories and consumers. A combined quantitative and qualitative analysis approach, incorporating severity and occurrence risk levels assessed by each respondent, was used. The application of the Supply Chain Operation Reference (SCOR) model revealed 21 risk events and 23 risk agents. Notably, risk agents such as adverse weather conditions, weak contractual agreements with suppliers, adverse weather during production and delivery processes, and damaged products displayed the highest ARP values (649, 826, 1521, 473, 276) across key business processes (plan, source, make, deliver, return). In response to these findings, proposed mitigation strategies include executing tasks during inclement weather, managing raw material inventory, establishing fair long-term contractual agreements with suppliers, selecting appropriate transportation during adverse weather, and choosing high-quality suppliers. This research contributes to the field of supply chain management by addressing gaps in risk mitigation within the brick manufacturing sector. The combination of the HoR methodology and ARP provides a comprehensive framework for identifying, assessing, and mitigating risks, thereby enhancing the resilience of the supply chain. The

results are particularly relevant for practitioners seeking effective strategies to manage risks in brick manufacturing and other similar industries.

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1. Introduction

Supply Chain Management (SCM) plays a pivotal role in the manufacturing industry, serving as a comprehensive system that orchestrates the flow of goods and services from production to end-user delivery [1]. In the face of inevitable uncertainties, both internal and external to organizations, effective SCM becomes crucial for ensuring operational efficiency and customer satisfaction [2].

Previous studies have underscored the inevitability of uncertainties in business operations and the need for meticulous risk management across various organizational activities [3]. Within the SCM domain, risks can manifest as disruptions or disturbances caused by events that adversely impact business processes [4]. For brick manufacturing factories, a critical risk lies in the instability of raw material supply, a factor that directly influences production processes and operational costs [5].

To address supply chain risks effectively, the House of Risk (HoR) methodology emerges as a valuable tool. This method involves a two-phase approach: the first phase entails the identification of risks and risk agents, measurement of severity and occurrence risk levels, and the calculation of Aggregate Risk Potential (ARP) values. In the second phase, prioritized risk handling strategies are developed based on the identified risks and their ARP values [6].

The brick manufacturing sector in Aceh Besar Regency, being an integral part of the manufacturing industry, is not immune to the challenges posed by supply chain risks. One prominent risk revolves around the instability of raw material supply, which can disrupt production processes, lower productivity, and escalate operational costs.

This research focuses on the development of effective risk mitigation strategies tailored to the SCM context of brick manufacturing factories in Aceh Besar Regency. Additionally, the study explores the application of the House of Risk (HoR) methodology as a tool for identifying, assessing, and managing risks inherent in the supply chain processes within these manufacturing facilities.

The objectives of this research encompass the design of tailored risk mitigation strategies specific to the SCM challenges faced by brick manufacturing factories in Aceh Besar Regency. Additionally, the study aims to implement the HoR methodology, providing a systematic approach for identifying, assessing, and managing risks within the supply chain processes of these manufacturing facilities. The application of the HoR model facilitates the calculation of ARP matrices, aiding in the identification of risk causes and the formulation of prioritized risk mitigation strategies.

2. Literature Review

2.1. Supply Chain Management

Supply Chain Management (SCM) entails the planning and management of all activities involved in the procurement, production, warehousing, and distribution of products [7]. This encompasses the movement and storage of raw materials, work-in-progress, and finished products from the point of origin to the point of consumption. The primary objective of SCM is to foster good relationships from upstream (suppliers) to downstream (consumers) by creating high-quality products [1].

From the above literature review, it can be concluded that Supply Chain Management (SCM) involves the planning and management of all activities related to the procurement, production, warehousing, and distribution of products. This includes the movement and storage of raw materials, work-in-progress, and finished products from the point of origin to the point of consumption [source]. The primary objective of SCM is to build good relationships from upstream (suppliers) to downstream (consumers) by creating high-quality products [1].

The significance of SCM as an integral approach in supply chain management is evident in the literature, particularly in the context of Supply Chain Risk Management (SCRM). SCRM is described as the process of detecting, analyzing, and managing risks associated with the global and dispersed information and communications technology structure [8]. Furthermore, the literature highlights how risks in SCM can stem from various sources, including economic, environmental, political, and ethical risks [9].

Through a comprehensive understanding of these risks, especially in the context of an increasingly complex supply chain, organizations can develop effective risk management strategies. This includes the identification, evaluation, management, and monitoring of these risks within the supply chain [10].

Thus, the literature indicates that SCM is not just about daily operations in the supply chain but also involves continuous risk management strategies, especially in the face of global dynamics and rapidly evolving technology. The adoption of good SCM practices, such as supplier diversification, building strong relationships, and investing in technology, becomes key in managing risks and enhancing supply chain performance [11].

2.2. Construction Supply Chain

The Construction Supply Chain (CSC) involves a network of organizations from upstream to downstream engaged in activities to produce valuable construction goods and services (outputs) for the ultimate customer [12]. In the execution of construction work, the flow of goods and services is centralized to the contractor, as the contractor acts as the primary executor of construction work according to the specifications set by the owner [13]. This integration of construction activities into the broader framework of SCM underlines the interconnectedness and collaborative efforts required for successful construction project delivery [14].

doi.org/10.32388/FSJF2F.2

Fig.1. *Supply Chains Construction and Networks* [14]

Supply Chain Management (SCM) in the construction industry involves the examination and management of interactions and integration among stakeholders throughout the provision of goods and services, from material extraction to consumption. Construction Supply Chains (CSCs) are unique due to the heterogeneous nature of construction projects and temporary contractual relationships. CSCs form networks of stakeholders engaged in value-adding activities within the construction industry, requiring effective management practices to overcome inherent challenges [15].

Integration is a fundamental aspect of SCM, aiming to improve overall supply chain performance. External integration involves collaboration with external stakeholders along the construction value-adding chain, while internal integration optimizes CSC functions at an intra-organizational level. Both internal and external integrations contribute to enhanced financial and green performance for construction suppliers and improved productivity for subcontractors. Effective CSCM practices not only benefit project outcomes but also align with long-term competitiveness development.

In Construction Supply Chain Management (CSCM), supply chain capacity plays a crucial role as a critical enabler for Construction Supply Chain Resilience (CSCR). Existing literature highlights the effectiveness of having back-up suppliers as a strategy to enhance resilience. This approach, distinct from material backorders, addresses quantity discrepancies that can only be fulfilled by suppliers at a future time due to

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capacity restrictions. However, there is a notable gap in the literature regarding the incorporation of back-up suppliers into CSC planning and the cost-effectiveness of this strategy compared to backordering [12].

Building a resilient supply chain involves making trade-offs between enhancing flexibility and redundancies while maintaining leanness. A lean supply chain, characterized by low or no inventories, contrasts with the resilience paradigm. Therefore, research attention is needed to explore the cost implications and risk mitigation effects of inventory management in a resilient CSC [12].

The literature supports the integration of Construction Supply Chain activities into the broader framework of SCM. This integration allows for a more comprehensive understanding of how effective SCM practices, including risk management and technological adoption, are essential for the successful execution of construction projects. The Construction Supply Chain, as an integral part of SCM, requires a strategic and collaborative approach to meet the objectives of delivering high-quality construction goods and services to the ultimate customer [16].

2.3. Brick Processing

Brick is a material used in wall construction, crafted from clay fired at high temperatures until it takes on a reddish hue [17]. Within the broader context of Supply Chain Management (SCM), it is imperative to consider specific elements such as brick processing, which constitutes a critical aspect of construction materials. Brick, as a fundamental material in wall construction, undergoes a meticulous manufacturing process involving various stages, such as raw material procurement, material processing, molding, drying, firing, cooling, and marketing [18]. The quality of bricks, a paramount concern in construction, is notably affected by the firing temperature employed during the manufacturing process [19].

The Brick Processing supply chain involves the procurement of raw materials, primarily clay, which is then subjected to a series of manufacturing steps to transform it into the final construction material [20]. The molding, drying, and firing stages are particularly crucial in ensuring the quality and integrity of the bricks [18]. Notably, the firing temperature plays a pivotal role in determining the characteristics of the bricks, and meticulous control of this parameter is essential for obtaining well-formed and perfect bricks [21].

Moreover, as technological advancements continue to shape SCM practices, it is essential to explore how innovations can be integrated into brick processing. The literature on SCM, including insights from Construction Supply Chain activities, emphasizes the role of technology such as advanced analytics and information sharing [22]. Considering this, future developments in brick processing could potentially benefit from technology adoption to enhance efficiency and quality control throughout the manufacturing stages [23].

Integrating brick processing into the broader SCM perspective highlights the intricate processes involved in manufacturing bricks and their significance in construction activities. By examining the supply chain elements specific to brick processing, it becomes evident that SCM principles can contribute to optimizing the manufacturing process, ensuring the consistent production of high-quality bricks, and meeting the demands of the construction industry [14].

2.4. Risk Management

Risk management is a concerted effort aimed at identifying, analyzing, and controlling risks inherent in every facet of company operations, ultimately geared towards achieving higher effectiveness and efficiency [24]. Within the broader SCM framework, risk management plays a pivotal role in ensuring the resilience and adaptability of supply chains to uncertainties. The risk management process, characterized by a systematic approach to handling uncertainties in a structured manner, comprises a series of steps that create a cyclical and adaptive process [25]. These steps are designed to empower organizations in navigating uncertainties effectively, fostering an environment where informed decisions can be made to enhance the likelihood of successful project outcomes.

As organizations engage in the procurement, production, warehousing, and distribution of products within the SCM spectrum, they are inherently exposed to various risks, ranging from economic and environmental factors to geopolitical instability and cyber threats [26]. Given this landscape, a robust Risk Management framework becomes indispensable in mitigating potential disruptions and safeguarding the continuity of supply chain operations.

Risk management in project management, and various risk factors that can influence time and cost in a project. Here are the key points [27]:

doi.org/10.32388/FSJF2F.2

1. Project risk is defined as the effect of uncertainty probabilities accumulation that influences the project target and goal. Risks are related to the possibility of unexpected or uncertain adverse conditions.
2. Risk growth in a project comes from various activities that can impact cost, schedule, and project quality.
3. Risk management is the process of identifying, measuring, and ensuring risks, as well as developing strategies to manage them. In project management, project risk management is described as both an art and a science. It involves identifying, analyzing, and responding to risks throughout the project period to ensure the achievement of project targets.
4. Various risk factors can influence project time and cost, including contractual risk, construction risk, material and equipment risk, design and technology risk, and force majeure risk.
5. The dominant risk, with the highest value, is indicated as the "wrong implementation" with a value of 7.50. The response to this dominant risk is described as coordination and consultation with the supervision and owner.

The information provided outlines the fundamental concepts of project risk, the importance of risk management in project management, and specific risk factors that can impact project outcomes. The focus on risk acceptability levels and response strategies indicates a proactive approach to managing and mitigating risks in a project.

The risk management process is a systematic approach to handling uncertainties in a structured manner. These steps create a cyclical and adaptive process, allowing organizations to navigate uncertainties effectively and make informed decisions to enhance the likelihood of successful project outcomes [28].

Fig.2. *Risk Management Process* [28]

The synergy between risk management and SCM is evident in the cyclical nature of the risk management process, aligning with the dynamic and interconnected elements of supply chain activities. By proactively addressing and mitigating risks, organizations can enhance the overall effectiveness and efficiency of their supply chains, contributing to the overarching goal of fostering good relationships from upstream (suppliers) to downstream (consumers) [9].

Risk management, a widely used analysis model, proves instrumental in minimizing the complexity and cost escalation of projects. Categorically, supply chain risks are classified into internal and external types, where external factors include demand risks, supply risks, environmental risks, and business risks. Similarly, internal risks comprise manufacturing risks, planning risks, control risks, business risks, and contingency risks [29].

In recent years, supply chain risk management (SCRM) has emerged as one of the most captivating and pivotal research areas. This field not only contributes to enhancing customer support but also plays a crucial role in driving high-profit revenues and facilitating organizational growth. A notable focus in this research is the comprehensive exploration of the top 5 global businesses that employ the SCRM model, with the primary objective being to conduct an in-depth case study [29].

2.5. House of Risk

The House of Risk (HoR) is a contemporary method for risk analysis. Its application involves the principles of Failure Mode and Error Analysis (FMEA) to quantitatively measure risks, combined with the House of Quality (HoQ) model to prioritize risk agents that require immediate attention. There are two phases of the HoR model, both modifications of the HoQ model [6].

2.5.1. HoR Phase 1

In the initial phase of the House of Risk (HoR) methodology, referred to as HoR Phase 1, the overarching objective is to pinpoint and prioritize risk agents for subsequent preventive actions. This phase is characterized by a systematic process involving the identification of risk agents and associated risk impacts, commonly referred to as risk events. This identification is facilitated through the administration of questionnaires, followed by a comprehensive

doi.org/10.32388/FSJF2F.2

assessment of each identified risk agent [30]. The crux of HoR Phase 1 lies in evaluating and assigning values to the identified risk agents, with a focus on determining primary priorities for intervention. The prioritization process involves ascertaining the Aggregate Risk Priority (ARP), a crucial metric used to gauge the significance of each risk agent in the context of potential preventive actions. The formula employed for calculating ARP (Equation 1) is defined as follows:

$$\mathrm{ARPj} = \mathrm{Oj}\ \Sigma \mathrm{i}\ \mathrm{Si}\ \mathrm{Rij} \quad (1)$$

Where:

- ARP = Aggregate Risk Priority
- O = Occurrence
- S = Severity
- R = Relationship (Correlation)

In essence, ARP serves as a weighted composite measure, combining factors such as occurrence, severity, and relationship, to provide a holistic assessment of the risk posed by each agent. The resulting ARP values guide the identification of primary priorities, directing attention and resources toward those risk agents deemed to have the highest impact and necessitating immediate preventive actions. This quantitative approach in HoR Phase 1 lays the foundation for a targeted and strategic risk management process.

2.5.2. HoR Phase 2

In the analytical framework of HoR Phase 2, the primary objective is to delineate the actions or interventions that should be implemented based on the outcomes derived from HoR Phase 1 [30]. The systematic steps involved in conducting HoR analysis Phase 2 are outlined as follows:

a. Selection of Top 5 Ranked Risk Agents: The initial step is to identify and select the top 5 risk agents based on their calculated Aggregate Risk Priority (ARP) values obtained from HoR analysis Phase 1.
b. Determination of Correlation Relationship (R): Subsequently, the correlation relationship (R) between each Proactive Action (PA) and the identified risk agent is established.
c. Calculation of Total Effectiveness (TE): The Total Effectiveness (TE) for each proactive action is computed using the formula:

$$\mathrm{TEk} = \Sigma \mathrm{j}\ \mathrm{ARPj}\ \mathrm{Ejk}\ \mathrm{TEk}\ = \Sigma \mathrm{j}\ \mathrm{ARPj}\ \mathrm{Ejk} \quad (2)$$

Where:

- TEk = Total Effectiveness
- ARP = Aggregate Risk Potentials
- Rjk = Relationship (Correlation)

d. Calculation of Effectiveness to Difficulty (ETD) Value: The next step involves calculating the Effectiveness to Difficulty (ETD) value using the formula:

$$\mathrm{ETDk} = \mathrm{TEk}/\mathrm{Dk}\ \mathrm{ETDk}\ = \mathrm{TEk}/\mathrm{Dk} \quad (3)$$

Where:

- ETDk = Effectiveness to Difficulty
- TEk = Total Effectiveness
- Dk = Degree of Difficulties (0, 3, 6, 9). e. Rank the top 5 values of Effectiveness to Difficulty (ETD)

e. Ranking of Top 5 ETD Values: The final step entails ranking the top 5 values of Effectiveness to Difficulty (ETD). This ranking provides a prioritized list of proactive actions based on their perceived effectiveness relative to the associated difficulties.

2.6. Supply Chain Operation Reference (SCOR) Model

The Supply Chain Operation Reference (SCOR) model, a pivotal framework in supply chain management, serves as an invaluable tool for delineating the intricacies of the supply chain components. It provides manufacturing facilities with a comprehensive framework that enables the articulation of a detailed understanding of the supply chain dynamics [31]. Central to its utility is the definition and categorization of business processes, constructing matrices and measurement indicators that are essential for a thorough assessment of supply chain performance [14].

Structured across three levels of processes, the SCOR model facilitates a hierarchical representation, ranging from a general overview to detailed insights into supply chain operations. This hierarchical approach extends to the assessment matrices, which are expressed in a format that aligns with the hierarchical evaluation of processes. The SCOR model systematically organizes supply chain processes into five main categories: plan, source, make, deliver, and return [32].

This model not only provides a structured mapping of supply chain processes but also offers a versatile approach to evaluating and enhancing supply chain performance. The SCOR model's hierarchical framework proves instrumental in fostering a nuanced understanding of the interconnected processes within the supply chain, thereby empowering organizations to make informed decisions and optimize their supply chain operations [32].

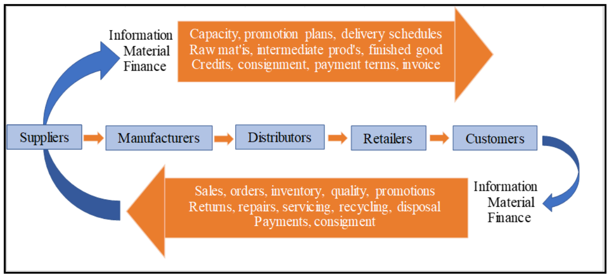

Fig.3. *SCOR Model* [33]

The SCOR model, introduced by the Supply Chain Council in 1996, serves as a foundational framework for dividing the supply chain into standardized business processes and categories. This structured approach facilitates a comprehensive analysis of information, financial, and product flows across the entire value chain, promoting a systematic evaluation of supply chain operations. Companies leverage this standardized structure to conduct cross-company analyses, enabling efficient planning over long-, medium-, and short-term horizons. The SCOR model empowers organizations to enhance the efficiency and effectiveness of their supply chain management [33].

Initially established by a consortium of companies, the Supply Chain Council aimed to optimize the value chain through the SCOR model. Over time, the model has undergone various adjustments, evolving into an industry-independent framework for making informed corporate and supply chain decisions. The 12th version of the SCOR model, published by APICS (the Association for Operations Management) in 2017, reflects ongoing advancements in supply chain practices. Notably, this version integrates metadata, blockchain, and omnichannel considerations as part of the evaluation processes, acknowledging the evolving landscape of technology and business strategies.

3. Methods

This study adopts a mixed-methods approach, combining quantitative and qualitative methods to provide a comprehensive analysis of risk management in brick manufacturing supply chains.

3.1. Quantitative Phase

In the quantitative phase, the research focuses on risk identification, risk assessment, risk prioritization, and risk evaluation within the brick manufacturing supply chain. This data-driven approach aims to quantify and prioritize risks based on predefined criteria.

3.2. Qualitative Phase

The qualitative phase involves direct observation at brick manufacturing plants, offering an in-depth exploration of how risks manifest in day-to-day operational activities. Additionally, interviews are conducted with key stakeholders involved in supply chain activities within the brick manufacturing plants in Aceh Besar Regency.

Direct observation provides valuable insights into the actual occurrence of risks, allowing researchers to observe and document risk factors and their impact on the supply chain processes. Interviews with relevant stakeholders, including supply chain managers, workers, and other personnel, are conducted to capture diverse perspectives on risks. These interviews aim to understand stakeholders' experiences, perceptions, and insights regarding identified risks and potential mitigation strategies.

By employing both quantitative and qualitative methods, this research design ensures a robust and holistic examination of risk management practices in the brick manufacturing supply chain. The combination of numerical data and qualitative insights enriches the analysis, providing a more nuanced understanding of the challenges and opportunities in this specific supply chain context.

3.3. Research Location

The research is carried out at three strategically selected brick manufacturing plants situated in Aceh Besar Regency. The selected plants are outlined as follows:

1. Plant X: Located in Lampoeh Dayah Village, Darussalam Sub-District, Aceh Besar Regency.
2. Plant Y: Located in Miruek Taman Village, Darussalam Sub-District, Aceh Besar Regency.
3. Plant Z: Located in Lam Rabo Village, Kuta Baro Sub-District, Aceh Besar Regency.

The choice of these specific plants aims to ensure a diverse representation of brick manufacturing operations within Aceh Besar Regency, providing a comprehensive perspective on the challenges and risk

doi.org/10.32388/FSJF2F.2

management practices prevalent in the region. The random selection method enhances the study's validity and applicability to the broader context of brick manufacturing supply chains in the specified geographical area.

3.4. Sampling Technique and Sample Size Determination

The sampling technique employed in this study involves purposive sampling, wherein the selection of brick manufacturing plants is based on specific criteria related to geographical location, production capacity, and operational practices. Purposive sampling allows for the selection of plants that are most representative of the brick manufacturing landscape in Aceh Besar Regency, ensuring that the findings are applicable to similar contexts.

The sample size determination is based on the principle of saturation, wherein data collection continues until no new information or insights emerge from additional observations or interviews. Saturation ensures that the sample size is sufficient to capture the diversity of perspectives and experiences within the selected plants, thereby enhancing the validity and reliability of the study findings.

3.5. Data Collection

The data collection process involves multifaceted approaches, encompassing direct field observations, structured interviews, and comprehensive questionnaire responses. Primary data acquisition targets factory owners, workers, and consumers actively engaged in diverse facets of supply chain activities within the brick manufacturing domain.

Additionally, secondary data is gleaned from existing factory records and profiles, providing valuable contextual information. The integration of both primary and secondary data sources ensures the research attains a robust foundation, allowing for nuanced insights into the intricacies of supply chain operations and associated risk factors within the brick manufacturing sector in Aceh Besar Regency.

3.6. Data Processing

The data processing phase involves a systematic approach to derive meaningful insights and actionable strategies. The following steps outline the comprehensive data processing methodology:

1. Mapping Supply Chain Activities Based on SCOR: Leveraging the SCOR model, the current supply chain processes are meticulously mapped, categorizing activities into the quintessential processes of planning, sourcing, making, delivering, and returning.
2. Risk Identification using FMEA: Employing the Failure Mode and Effect Analysis (FMEA) method, risks are identified and categorized into controllable and uncontrollable domains. A thorough compilation of potential risks is derived from on-site surveys, interviews, and detailed questionnaires.
3. Identifying Causes of Risks: The causes underlying the identified risks are systematically determined, recognizing the intricate relationships where one risk event may be instigated by multiple risk agents, and vice versa. The probability of occurrence of these risk agents is rigorously assessed, influencing the likelihood of subsequent risk events.
4. Correlation Identification: The correlation between risk events and risk agents is established using the House of Risk (HoR) phase 1 model. Correlation values are evaluated, with assigned values of 1, 3, and 9 indicating the strength of the correlation between risk agents and events.
5. Designing Risk Source Handling Strategy: Leveraging the HoR phase 2 model and a comprehensive risk map, strategies for handling each identified risk source are meticulously crafted. These strategies undergo expert evaluation, with each strategy assigned a corresponding difficulty level (Dk).
6. Recommendation for Improvement: Focused on the five core components of the SCOR model, a HoR phase 2 table is created for each component. This table acts as a conduit, establishing connections between prioritized risk sources and the tailored handling strategies designed for each specific business process.

The systematic execution of these data processing steps ensures a robust and nuanced understanding of the supply chain dynamics, risk factors, and strategic interventions within the context of brick manufacturing in Aceh Besar Regency.

3.7. Data Analysis

The data analysis phase is pivotal in synthesizing insights drawn from discussions and interviews with key stakeholders, including factory owners, workers, and consumers. The multifaceted approach encompasses the following key elements:

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1. Expert Discussions and Interviews: Insights gathered through discussions and interviews with industry experts, including factory owners, workers, and consumers, provide qualitative inputs into the assessment of risks within the brick manufacturing supply chain.
2. Prioritization Through HoR Phase 1: The prioritization of risks is informed by the comprehensive assessment derived from the House of Risk (HoR) phase 1 questionnaire. The prioritized risks, identified through quantitative measures, lay the foundation for focused intervention strategies.
3. Risk Mitigation Strategies - HoR Phase 2: Building on discussions and responses obtained from the HoR phase 2 questionnaire, risk mitigation strategies are formulated. These strategies are meticulously designed to address the prioritized risks, taking into account the correlation values and the overall effectiveness to difficulty ratios.

By integrating these data analysis components, this study aims to present a holistic view of the risk landscape in brick manufacturing, offering informed insights into the strategic interventions necessary for bolstering the resilience and efficiency of the supply chain in Aceh Besar Regency.

4. Results and Discussion

4.1. Respondent Characteristics

The characteristics of the respondents play a crucial role in understanding the perspectives and experiences shaping the brick manufacturing supply chain in Aceh Besar Regency. The demographic data of the 12 participants are summarized in Figure 4.

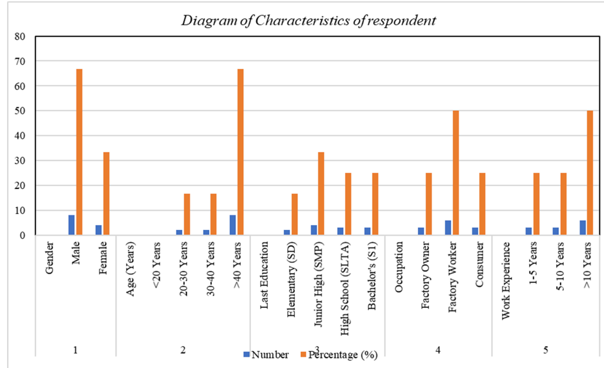

Fig.4. *Characteristics of respondents*

The majority of respondents were male (66.67%), with a significant portion aged over 40 years (66.66%). The last educational attainment predominantly included junior high school (33.33%), and the majority held positions as factory workers (50.00%). Additionally, 50.00% of respondents had work experience exceeding 10 years, showcasing a seasoned perspective on the brick manufacturing industry. These demographic insights lay the foundation for a comprehensive understanding of the challenges and opportunities within the sector.

4.2. Mapping of Supply Chain Activities

The SCOR model categorizes supply chain activities into distinct processes: plan, source, make, deliver, and return. This categorization allows a structured understanding of interconnected activities within the brick-manufacturing industry. The mapping of these activities is depicted in Table 1, providing a visual representation of each process and its corresponding activities.

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Process	Activity
Plan	Planning raw material procurement
	Planning production work
	Scheduling shifting raw material work
Source	Supplier selection
	Material selection
	Material procurement process
Make	Production execution not according to plan
Deliver	Delivery of raw materials/materials
Return	Return of finished products from consumers

Table 1. *Mapping of supply chain activities*

Table 1 illustrates the mapping of supply chain activities according to the SCOR model. Each process, including planning, sourcing, manufacturing, delivery, and returns, is broken down into specific activities relevant to the brick manufacturing industry. This mapping serves as a foundational framework for analyzing and optimizing the supply chain processes.

4.3. Risk Identification

Following the mapping of supply chain activities, the next step involved the identification of potential risk events and their corresponding risk agents within the brick manufacturing process in Aceh Besar Regency. The identified risk events and risk agents are presented in Table 2.

doi.org/10.32388/FSJF2F.2

Risk Event	Risk Agent
Delay in the arrival of raw materials	Traffic congestion
Sudden changes in work plans	Uncertainty of material delivery by suppliers
Errors in planning procurement of raw materials	Errors in scheduling raw material needs
Delay in completing one work process	Influence of bad weather
Miscommunication with suppliers and sub-contractors	Workers not following SOP
Difficulty in obtaining materials/raw materials	Weak agreement/contract with the supplier
Low supplier ability to meet quality demands	Material scarcity
Delay in the arrival of raw materials	Price misalignment with the quality of raw materials
Supplier unable to meet the quantity of raw materials	Material not meeting specifications
Unconducive working environment	Limited stock of materials
Inadequate raw materials for production	Shortage of material suppliers
Dough damage in the production process	Overcrowded workspace
Production output does not meet targets	Bad weather (rainy season)
Waiting for the repair of a damaged machine	Delay in the arrival of materials
Lack of quality checks on production results	Machine breakdown during work
Weather influence	Human error
Error in the schedule for delivering products to customers	Bad weather
Delay in product delivery to consumers	Product shortages (bricks)
Return of raw materials/materials to the supplier for various reasons	Difficulty in obtaining products (bricks)
Large number of products returned (returns) by distributors or stores selling directly to main stores/production places	Far distance from the factory
Complaints from consumers/distributors	Narrow factory entrance
	Raw materials/products received do not match the agreed specifications
	Raw materials/products arrive damaged

Table 2. *Identified risk events and risk agents*

These identified risk events and risk agents form the basis for further risk assessment and prioritization in the subsequent sections of the study.

4.3.1. HoR Phase 1

Following the identification of risks, the severity level of each risk event and the occurrence level of likelihood for each risk agent were assessed on a scale of 1–10. Additionally, the correlation between risk events and risk agents, denoted by values of 1, 3, and 9, was evaluated. The assessment data, based on the House of Risk (HoR) Phase 1 model, were used to determine the ranking of risk agents.

Code	Risk Agent	ARP	Pj
A1	Traffic congestion	503.4	8
A2	Uncertainty in material delivery time by supplier	258.2	18
A3	Errors in scheduling raw material needs	573.1	7
A4	Influence of bad weather	648.9	6
A5	Workers not following SOP	438.7	12
A6	Weak agreements/contracts with supplier and sub-contractor	825.9	4
A7	Material scarcity	419.6	13
A8	Mismatch of price with raw material quality	370.2	14
A9	Material not meeting specifications	439.4	11
A10	Limited material stock	232.6	19
A11	Shortage of material suppliers	217.5	20
A12	Overcrowded workspace	441.9	10
A13	Bad weather (rainy season)	1521	1
A14	Delay in material arrival	697.7	5
A15	Machine breakdown during work	855.8	3
A16	Human error	966.9	2
A17	Product shortage (bricks)	168.4	21
A18	Bad weather	472.8	9
A19	Difficulty in obtaining products (bricks)	142.7	23
A20	Far distance from the factory	153.9	22
A21	Narrow factory entrance	313.1	15
A22	Raw materials/products not meeting specifications	260.3	17
A23	Raw materials/products arrive damaged	276.2	16

Table 3. *Risk agents based on ARP and Pj*

These rankings provide insights into the prioritization of risk agents based on their Aggregate Risk Priority (ARP) and Pj values, forming a foundation for subsequent risk mitigation strategies in HoR Phase 2.

4.3.2. HoR Phase 2

Building upon the assessments conducted in HoR Phase 1 and the obtained Aggregate Risk Priority (ARPj) values, the subsequent step involves the implementation of risk mitigation through HoR Phase 2. This phase focuses on executing risk treatment strategies for identified risk agents with the highest ARPj values.

Risk Agent	Treatment Strategy
Bad weather (rainy season)	Perform tasks that can be done during bad weather, such as brick printing and drying at room temperature. Choose appropriate transportation for material and product delivery during bad weather.
Human error	Maintain consistency and commitment in performing tasks and conduct human resources training.
Machine breakdown during work	Double-check machines before processing raw materials.
Weak agreements/contracts with supplier	Renegotiate contracts with fair and mutually beneficial long-term working agreements. Implement stock strategies by rechecking product orders, delivery schedules, and product evaluations.
Late and damaged product arrival	Strengthen product specifications with the supplier, including clear size, material, color, strength, and other relevant attributes. Request product delivery as agreed initially.

Table 4. *HoR phase 2 and treatment strategies*

These treatment strategies aim to proactively address and mitigate the identified risks, providing a framework for risk management within the brick manufacturing supply chain in Aceh Besar Regency.

5. Discussion

The study underscores the importance of implementing effective risk mitigation strategies in the realm of brick manufacturing. The mapping of supply chain activities using the SCOR model offers a systematic approach to understanding the various stages involved in brick manufacturing. By categorizing activities into distinct processes, such as planning, sourcing, and manufacturing, we can identify areas for improvement and optimization within the supply chain.

For instance, in the planning phase, activities such as raw material procurement planning and production scheduling are crucial for ensuring an efficient supply chain flow. By analyzing these activities, organizations can better anticipate demand fluctuations and optimize inventory management practices.

Similarly, in the manufacturing phase, the execution of production processes not according to plan can lead to inefficiencies and delays. By closely monitoring and aligning production activities with predetermined schedules, organizations can minimize disruptions and improve overall productivity.

Moreover, the identification of risk events and corresponding risk agents, as outlined in Table 2, further enhances our understanding of potential disruptions within the supply chain. By addressing these risks proactively, organizations can mitigate potential impacts on production timelines and customer satisfaction.

While this study endeavors to provide valuable insights into risk management within the brick manufacturing sector in Aceh Besar Regency, it is essential to acknowledge its limitations. Firstly, the research focuses solely on brick manufacturing factories within a specific geographical area, potentially limiting the generalizability of the findings to other regions or industries. Additionally, the study's reliance on the House of Risk methodology may overlook alternative approaches or perspectives to risk assessment and mitigation. Furthermore, the sample size and selection method may introduce biases and limitations in representing the diversity of brick manufacturing operations in the region. Finally, the dynamic nature of supply chain risks and the evolving landscape of the brick manufacturing industry may render some findings outdated or less applicable over time. Despite these limitations, this research provides valuable insights into risk management practices within the brick manufacturing sector, laying the groundwork for future studies to address these constraints and further enhance our understanding of supply chain resilience and risk mitigation strategies.

Overall, the utilization of the SCOR model provides a structured framework for analyzing and optimizing supply chain activities within the brick manufacturing industry. By leveraging this model in conjunction with risk identification and mitigation strategies, organizations can enhance operational efficiency and resilience in the face of uncertainties.

6. Conclusion

The study emphasizes the critical importance of implementing effective risk mitigation strategies within the brick manufacturing sector in Aceh Besar Regency. The proposed House of Risk methodology offers a structured approach to address key challenges in supply chain management specific to the brick industry. Key insights gleaned from the findings include the imperative to enhance internal processes for raw material scheduling, conduct thorough supplier evaluations, develop alternative production plans for adverse weather conditions, implement meticulous delivery planning, maintain effective communication with customers, and establish a continuous monitoring and evaluation system throughout the supply chain. Upon implementation, these strategies are expected to mitigate priority risks within brick factories, ensuring sustainability and enhancing the well-being of owners, workers, and consumers involved in the supply chain.

Practical recommendations for practitioners include enhancing internal processes for raw material scheduling to optimize inventory management and minimize production disruptions, conducting comprehensive supplier evaluations to ensure reliability and consistency in raw material supply, developing alternative production plans to mitigate the impact of adverse weather conditions on manufacturing operations, implementing meticulous delivery planning to streamline logistics and enhance customer satisfaction, maintaining effective communication channels with customers to address concerns and ensure timely delivery of products, and establishing a continuous monitoring and evaluation system throughout the supply chain to identify potential risks and opportunities for improvement.

In terms of future research directions, one potential avenue involves analyzing employee performance through Key Performance Indicators (KPIs) to further support the implementation of mitigation strategies. Additionally, exploring advanced technologies such as predictive analytics and artificial intelligence in supply chain risk management could offer valuable insights for enhancing operational efficiency and resilience. By embracing these recommendations and exploring future research directions, brick factories can achieve overall operational improvements and enhance risk management practices, benefiting stakeholders across the supply chain and fostering a more resilient and thriving industry.

Acknowledgements

The completion of this research project has been a collaborative effort, and I would like to express my sincere gratitude to those who have contributed to its realization. I would also like to thank the participants of this research, including the owners, workers, and consumers of the brick factory in Aceh Besar Regency. Their willingness to share valuable insights and experiences has been crucial to the depth and comprehensiveness of this study.

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Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.